Geologic Hazard Assessments Subactivity

Program	1999 Estimate	Uncontrol. & Related Chgs	Program Redirect	Program Changes	FY 2000 Budget Request	Change from 1999
Earthquake Hazards	**48,560**	**1,075**	**-7,120**	**1,600**	**44,115**	**-4,445**
Volcano Hazards	19,759	354	-2,845	-250	17,018	-2,741
Landslide Hazards	2,370	60	-237	0	2,193	-177
Global Seismographic Network	3,831	42	-392	0	3,481	-350
Geomagnetism	1,849	50	-296	400	2,003	154
Total Requirements $000	76,369	1,581	-10,890	1,750	68,810	-7,559

Note: The Program Redirect column reflects the redirection of funds to the Integrated Science, Science Support, and Facilities activities.

Earthquake Hazards

Current Program Highlights

The USGS Earthquake Hazards Program helps reduce deaths, injuries, and property losses from earthquakes through understanding of their characteristics and effects and by providing the information and knowledge needed to mitigate these losses.

The USGS Earthquake Hazards Program is a major component of the National Earthquake Hazards Reduction Program (NEHRP) authorized by P.L. 105-47. The program coordinates its activities with the three other principal NEHRP agencies, FEMA, NSF, and NIST. The USGS has the responsibility, within NEHRP, to identify and characterize earthquake hazards, to monitor seismic activity, and to conduct research in support of earthquake hazard assessments and loss reduction practices and strategies.

The USGS provides the professional expertise, technical resources, geographic extent, response capability, and the established reputation of scientific excellence and objectivity needed to address the responsibilities identified by NEHRP. Federal, State, and local government agencies, architects and engineers, insurance companies and other private businesses, land use planners, emergency response officials, and the general public all rely on the USGS for earthquake hazard information and knowledge. These and other products are used to refine building codes, develop land use strategies, safeguard lifelines and critical facilities, develop emergency response plans, and take other precautionary actions to reduce losses from future earthquakes.

The USGS contributes to earthquake hazard mitigation strategies by estimating and describing the likelihood and potential effects of moderate to large earthquakes in high risk regions of our country, and by transferring this knowledge to people and agencies that can reduce the impact of a significant earthquake. The USGS also responds to earthquake emergencies by rapidly characterizing the probable size and extent of damage, assessing the continuing risks from aftershocks and related ground-motion and ground-failure hazards, and facilitating the work of response officials.

The program provides critical earth-science information for understanding earthquakes and for identification and quantification of potential earthquake hazards throughout the United States. This information is used to design and improve strategies for reducing losses from future earthquakes and to provide the knowledge needed to respond to earthquake emergencies. The USGS supplies information on earthquake mitigation strategies to a large and diverse public and private user community.

External Cooperative Agreements and Grants — The USGS Earthquake Hazards Program supports a competitive, peer-reviewed, external program of cooperative agreements and grants that enlists the talents and expertise of State and local government, the academic community, and the private sector. The investigations and activities supported through the external program are closely coordinated with and complement the internal USGS program efforts. In general, routine monitoring efforts are supported through three-year cooperative agreements, research efforts are supported through one to two year grants. In FY 1999, 17 cooperative agreements were funded to support regional seismic monitoring efforts in various parts of the country. A total of 102 research grants were supported, 70 with universities and colleges, 8 with State Geological Surveys, and 24 with private sector companies. Actual funding provided is $3.0 million for regional networks, $6.0 million for research grants, and $1.17 million to support the Southern California Earthquake Center. Many of the external projects are co-funded with other agencies and sources, leveraging the effect of USGS support. External program activities include: monitoring and locating earthquakes by regional seismographic networks, mapping seismic hazards in metropolitan areas, developing credible earthquake planning scenarios including loss estimates, defining the prehistoric record of large earthquakes, investigating the origins of earthquakes, and improving methods for predicting earthquake effects. By involving the external community, the USGS program increases its geographical and institutional impact, promotes earthquake awareness across the Nation, encourages the application of new hazards assessment techniques by State and local governments and the private sector, and increases the level of technical knowledge within State and local government agencies. During FY 1997 through FY 1999, Congress provided $6.0 million for competitively awarded earthquake research grants. The FY 2000 request will maintain funding for research grants at $6.0 million.

Products for Earthquake Loss Reduction — USGS seismic shaking hazard maps for the conterminous United States are being used to develop new, unified building codes for the United States. These maps give in a digital format the maximum severity of ground shaking that can be expected during time periods of 50,100, and 250 years. These maps are also being used to predict earthquake losses and to define insurance risks. In 1998, a new map for

Alaska was produced. Similar maps are being produced for Hawaii and Puerto Rico/Virgin Islands. Periodic review and updating of such maps to incorporate new information is among the highest priorities for the USGS. Development of these maps involves extensive consultation with earthquake researchers, engineers, and State and local government representatives. The maps integrate geologic mapping; fault locations, fault slip rates, and earthquake recurrence intervals; and analyses of crustal deformation, ground-motion patterns, and recent seismicity. The USGS is working to improve the base of geologic data for preparation of the next generation of seismic hazard maps.

Earthquake Hazards Studies in Urban Areas — The USGS is generating products that address the hazards in high to moderate risk urban areas, where the population and risks are greatest, such as the San Francisco Bay area, Los Angeles, Seattle, Salt Lake, Memphis, and Charleston, South Carolina. During 1999 – 2001 particular attention will be paid to the Seattle, Memphis, and San Francisco areas. In these areas, ongoing geologic work defines local earthquake source zones and their earthquake histories. These results are used to develop local maps showing probabilities of earthquake occurrence, capabilities of geologic deposits to amplify shaking, and susceptibility of these deposits to liquefy and slide. Earthquake shaking scenarios are being developed for public planning, and modeling of ground motion is being provided for engineering applications. In conjunction with these products, the USGS conducts workshops to ensure the proper transfer of knowledge and to help design effective mitigation.

Figure G-1. This figure is one of many derivative products from the National Seismic Hazard Mapping Project. It shows the relative horizontal acceleration (shaking) at various cycle periods for major metropolitan areas. There is a 90% probability that the level shown (as % gravity) will not be exceeded in 50 years. This information is used in building design and loss estimation. In general, the seismic shaking is higher at shorter periods (higher frequencies) compared to longer periods (lower frequencies). Also, the general hazard in San Francisco and Los Angeles is about ten times that in Boston, but the hazard in Boston is not zero.

Regional Earthquake Monitoring — The USGS and cooperating universities operate regional seismic networks in areas of high seismicity. Data from all U.S. seismic networks are used to monitor active tectonic structures in much greater detail than is possible with the national scale network. Each region has a local data center where the data are processed and regional catalogues of earthquakes are produced. These data centers provide a local distribution point for information about earthquakes and earthquake mitigation practices. Many of the regional networks provide near real-time information on the occurrence of nearby earthquakes. The data centers at universities provide a training and research facility for students.

Monitoring Strong Motions Due to Earthquakes — Conventional seismometers used in earthquake monitoring networks cannot accurately record strong ground and building motions caused by large, nearby earthquakes. Yet this technical data is extremely valuable for the design of earthquake resistant buildings and other structures. Through the National Strong Motion Program the USGS maintains about 840 strong motion recorders at 540 sites in 35 States and territories. The strong motion data show the amplitude, frequency content, and duration of strong accelerations caused by an earthquake. These parameters are direct inputs to computer models and scale models of structures to test their performance under realistic earthquake shaking.

Monitoring Changes in Shape of the Earth's Surface — Geodetic networks provide essential
information about movement of the land surface near faults and earthquake source zones. The USGS is working with universities and local agencies to conduct geodetic investigations using the global positioning system (GPS) and laser ranging surveys. In cooperation with NASA and NSF, the USGS is testing new GPS monitoring capabilities in southern California. The USGS is also investigating a new satellite technology, Interferometric Synthetic Aperture Radar, that has the potential of quickly and accurately providing large areal maps of pre- and post-earthquake land deformation.

Post Earthquake Investigations — The USGS responds to large domestic earthquakes by deploying portable seismic and geodetic instrumentation, conducting detailed geologic field investigations, and evaluating damage patterns in relation to geologic conditions and effects. These investigations provide essential information during and immediately after the emergency and an opportunity to make substantial advances in our understanding of earthquake geology and engineering.

Additional Earthquake Research — The USGS conducts research that has significant potential for breakthrough discoveries in earthquake hazard assessment and mitigation. The research is interdisciplinary, peer-reviewed, and coordinated with external partners through grants and cooperative agreements. Research results are incorporated rapidly in USGS earthquake loss reduction products.

A major focus of USGS earthquake research is in understanding earthquake occurrence in space and time. Ongoing USGS investigations seek to understand: the physical conditions for earthquake initiation and growth; processes of earthquake triggering; how individual faults in the same region interact; why some faults slip seismically while others generate earthquakes; and the factors that control variations of recurrence intervals of earthquakes along the same fault.

USGS earthquake research also continues to address the problem of short-term warnings in the days or hours before damaging earthquakes. Well documented geologic and (or) hydrologic signals preceded the Loma Prieta and Kobe earthquakes, warranting thorough investigation of these phenomena. The ongoing USGS earthquake prediction experiment at Parkfield, California may permit not only the recording of pre-earthquake signals, but also the possibility of understanding their origin. USGS research has important applications in forecasting earthquake aftershocks and is of great value to citizens and public safety officials in the aftermath of large earthquakes.

Improving current techniques for forecasting the effects of strong ground motion will greatly improve seismic hazard maps for urban regions and is critical to cost-effective earthquake hazard mitigation. USGS earthquake research in this area addresses how complexities in the earthquake source, earth's crust, and near-surface soils and deposits influence seismic wave propagation and strong ground motion. Identifying and understanding the behavior of weak liquefiable sediments is also a priority. Research on ground failure in collaboration with structural and geotechnical engineers will lead to improved design of earthquake-resistant infrastructure.

Recent Accomplishments

Prehistoric Earthquakes in the San Francisco Bay Area — The USGS is working with the Pacific Gas and Electric (under a Cooperative Research and Development Agreement) and the Lawrence Livermore National Laboratory (LLNL) to develop a complete chronology of large earthquakes on major active faults in the San Francisco Bay area during the last 2000 years. The Bay Area Paleoearthquake Experiment (BAYPEX) involves digging trenches across active faults and detailed geological analyses of the trench walls to determine the history of earthquake occurrences for each fault. Charcoal samples taken from trench walls are collected for radiocarbon dating to help determine the absolute age of previous earthquakes. Some 23 sites are being excavated along surface traces of active faults to estimate the time and size of past earthquakes. The results are being used by the USGS to prepare a comprehensive statement on earthquake probabilities in the Bay area. Utility companies can use the results to determine the safes routes for power grids in the region.

Project IMPACT — Oakland, California, **and Seattle, Washington.** The USGS is supporting FEMA’s Project IMPACT by working with the cities of Oakland and Seattle in the assessment of earthquake hazards. Most of this work involves detailed mapping of the rock type at the surface and determination of its material properties using geophysical techniques. These results are in turn being used to identify those zones throughout these cities that are at highest risk from earthquake shaking. To support this project, the USGS has developed an inexpensive seismometer suitable for deployment in urban areas. These devices have been installed in downtown Oakland, near the approaches to the San Francisco Bay Bridge, and at the Oakland airport. They are collecting data from small, non-damaging earthquakes that indicate how individual sites will respond during a large earthquake. This innovative approach to seismic monitoring in urban regions could, if successful, greatly reduce the costs of monitoring these regions for earthquake response purposes and help define mitigation measures.

Passive seismic techniques must wait for a small earthquake to occur before the response to earthquake shaking of surface sediments can be measured. In Oakland, the USGS is using a active technique that involves driving a truck mounted steel rod up to 100 feet into the soil to determine material properties of the upper geologic layers. Based on this information, the amplification or attenuation of seismic shaking by the soil layers can be calculated.
In contrast to the San Francisco Bay region, the prehistoric earthquake pattern is difficult to assess in Seattle where the surface expressions of active faults are few and less obvious. Recently, a surface expression of the Seattle fault was found on Bainbridge Island using high-resolution laser ranging techniques. Sub-surface evidence for this fault had been found earlier using geomagnetic and seismic surveying techniques. Trenches were dug and evidence was found for prehistoric earthquakes on this fault. These results are undergoing interpretation; however, they present the first direct physical evidence for earthquake activity on the Seattle fault. These results are being used to review previous hazard assessments of the Seattle region.

In addition, the USGS has been working closely with civic and business interests in both Oakland and Seattle to promulgate information on earthquake hazards and to promote mitigation practices.

Earthquake Effects in Geologic Basins — Geologic basins filled with recent, loose sediments are known to amplify and extend seismic shaking from earthquakes. Unfortunately, these settings make attractive places for development. Mexico City in 1985 and Leninakan, Armenia, in 1988 are examples of severe earthquake damage to cities built over geologic basins. Over 10,000 people were killed in each of these cities when earthquake hit. USGS scientists have developed theoretical models of seismic wave propagation that explain the general features of amplification and extension of shaking in basins. For the past two years the USGS has conducted a pilot field experiment near Santa Clara, California (Silicon Valley). In this experiment dozens of portable seismometers have been recording small earthquakes that occur frequently in the region. These recordings have been used to refine the theoretical models and develop a basin response map. This map shows the sites within Santa Clara Valley that may be subject to particularly strong shaking during a large earthquake. Buildings occupying these sites may need strong reinforcement, and new buildings may need to be constructed at standards that exceed conventional building code requirements. If these pilot studies prove successful, the methods can be repeated at other densely populated cities built on geologic basins.

Southern California Earthquake Monitoring — "Shakemap". Project TriNet is a cooperative earthquake monitoring effort in southern California involving the California Institute of Technology, the California Division of Mines and Geology, and the USGS. Under this project, several hundred seismometers are being installed in the Los Angeles urban area. These instruments are capable of recording very strong earthquake shaking and transmitting the data to a Caltech/USGS data center for analysis. With new data and analysis procedures, an innovative product called "shakemap" can be produced within ten minutes of any earthquake in the region. These maps are posted on an Internet Web-site. The maps show the severity and distribution of ground shaking caused by the earthquake. Because of geologic factors, these patterns are not centered on the earthquake epicenter, and are often irregular showing pockets or zones of concentrated shaking. Emergency response officials, transportation and utility infrastructure managers, and police and fire officials are using these maps to plan and execute their response to earthquake emergencies.

National Earthquake Information Center (NEIC) — NEIC has continued to be the primary source for public information on earthquakes in the nation and worldwide. NEIC is responsible for notifying Federal and State emergency management officials of potentially damaging earthquakes within minutes of their occurrence. It also is the primary source of information on foreign earthquakes for the State Department, Red Cross, and other international relief organizations. During the past year, over 22,000 earthquake were located and reported by NEIC. In addition to its operational monitoring and notification activities, NEIC serves the Nation as an educational and information resource. The NEIC Web-site receives about 2 million “hits” per month, over 60,000 per day. It provides information on recent seismic activity and general information on earthquake occurrences, earthquake effects, and seismicity maps. A recent NEIC product is a seismicity map of Central America and the Caribbean region including Puerto Rico and the Virgin Islands. This is one of a series of wall size, regional seismicity map produced by NEIC over the past decade. These maps are extremely popular with high school and colleges as teaching aids. During 1999, a regional map showing seismicity in the northeastern United States will be completed.

Seismicity of the Northeastern United States: 1977 - 1998

Figure G-2. Earthquakes in the northeastern United States above magnitude 2.0 during 1977-1998.

Justification for Program Change

	FY 2000 Request	Program Change
$(000)	44,115	+1,600

Real Time Hazards (+$1.6 million) — In the minutes following a damaging earthquake in an urban area, there is a requirement for accurate information on the severity and distribution of strong ground shaking. Emergency managers, managers of transportation and utility networks, providers of public services and the public in general need this information quickly in order to respond promptly and effectively to the emergency. The USGS operates, or supports the operation of, regional seismic networks in areas of high to moderate seismic risk in the United States. In general, these seismic networks were designed and installed over twenty years ago for the purpose of monitoring the seismic activity of active faults. The existing instrumentation and data processing facilities are not adequate to give a timely, accurate, and detailed picture of the strong ground shaking across urban areas. A pilot project to address this problem, called TriNet, is underway in the Los Angeles region. This project has demonstrated that, with suitable equipment and data processing, maps showing the level and distribution of shaking can be produced automatically within minutes of an earthquake. The proposed increase would be used to purchase and install some 80 modern seismographs to initiate similar projects in San Francisco (40 stations), Seattle (20 stations) and Salt Lake City (20 stations). Complete capability will require significant future expansion of these pilot networks. USGS, through this effort, intends to provide the leadership that may encourage other Federal, regional, and local interests to participate as partners in joint efforts towards the realization of full scale coverage.